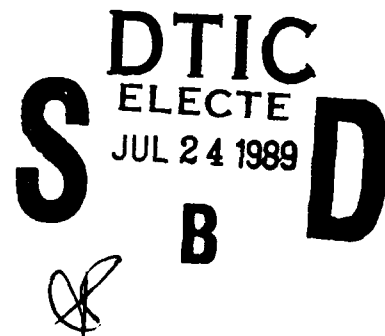


AD-A210 521

IFD: Interfaced With Harvard Open Ocean Model Forecasts

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Preface

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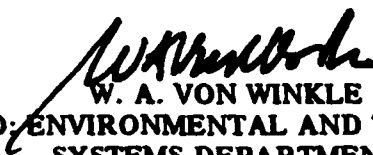
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SYSTEMS DEPARTMENT

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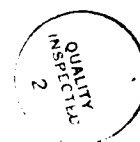
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<p>The capability to interface the implicit finite difference (IFD) computer model with mesoscale forecasts generated by the Harvard Open Ocean Model is announced. Given the latitude and longitude of the source location, the IFD model extracts from the 3-dimensional Harvard data set sound speed profiles encountered in the direction of propagation. Contour plots are presented of sound speed and temperature variability through a typical Harvard data set containing both warm- and cold-core eddies in the vicinity of the Gulf Stream. Acoustic propagation loss through a cold-core eddy is presented. A listing of the subroutine that links IFD with the Harvard data set is included.</p>					
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IFD: INTERFACED WITH HARVARD OPEN OCEAN MODEL FORECASTS

INTRODUCTION

In 1982, the implicit finite difference (IFD) computer model^{1,2,3} was developed by Lee and Botseas at the Naval Underwater Systems Center (NUSC) for solving the parabolic wave equation (PE).^{4,5} The IFD model was designed to predict acoustic propagation in both range-dependent and range-independent undersea environments. Given an environment, the IFD model marches the acoustics solution in the water column forward, step-by-step, until maximum range has been reached.

The environmental data input into the IFD model are generally based on previously measured data compiled by season for the geographic region of interest. If the region of interest is quiescent, then the data are typical and may be perfectly valid. However, if the environment is constantly undergoing dynamic change, the archival data alone are not sufficient and should not be solely relied on when planning for future military or scientific missions. A reliable system that is capable of nowcasting and forecasting accurate undersea environmental data in real-time would be extremely valuable. One system that is being refined for that purpose is the Oceanic Descriptive Predictive System (ODPS) developed at Harvard University by the Harvard Open Ocean Modeling Group.^{6,7,8,9}

This report presents a brief description of the ODPS and a discussion on subroutine USVP, which links the sound speed forecasts generated by the Harvard Open Ocean Model⁸ with IFD. Also included is the input runstream and initialization of USVP for a propagation loss prediction through a cold-core eddy. The discussion is aimed at experienced IFD users interested in linking with the Harvard data set and users who may have a need to modify USVP.

A listing of subroutine USVP can be found in the appendix.

THE HARVARD OCEANIC DESCRIPTIVE PREDICTIVE SYSTEM (ODPS)

One strategy for predicting the location and evolution of mesoscale phenomena in the ocean is the ODPS developed at Harvard University. Historical and telemetered real-time observations, collected by remotely located and in situ sensors, are combined by optimal estimation theory with estimates of undersea dynamics generated by statistical and dynamic models in a supercomputer. Theoretically, the expected error of the combined estimate is lower than the expected error of each individual estimate.⁹

One dynamic model, the Harvard Open Ocean Model,⁸ is currently employed in a predictive system that is nowcasting and forecasting, in real time, the basic physical fields of velocity, pressure, density, temperature, and salinity in the Gulf Stream region (GULFCASTING). Once predictions for the basic physical fields have been obtained, associated fields such as sound speed can also be predicted.

A typical data set generated by ODPS is the sound speed forecast shown in figure 1.¹⁰ The Gulf Stream, as it meandered west to east, gave birth to five distinct eddies. The three warm-core eddies north of the Gulf Stream trapped the warmer water from the Sargasso Sea, while the two cold-core eddies south of the stream contained colder slope water. The data domain shown in the figure is centered at 37° 30' N and 66° 48' W. The 810 km square domain is rotated 20° counterclockwise. This particular data set consists of 55 x 55 data points for a total of 3025 points per depth plane. Six depth planes (100, 300, 700, 1100, 2200, and 3900 m) were forecast. Distance between data points on any given plane is 15 km. Each plane of data is arranged in a separate array in an order such that points 1, 55, 2971, and 3025 represent the SW, SE, NW, and NE corners of the domain.

A contour plot of sound speed in the vertical plane is illustrated in figure 2. The transect (ABCDE) along which these data were obtained passes through, in order, a cold-core eddy, the Gulf Stream, and a warm-core eddy, as shown in figure 1.

Figures 3 and 4 are contour plots of temperature corresponding to the sound speed plots shown in figures 1 and 2.

Sound speed profiles extracted at points A, B, C, D, and E along the transect shown in figure 1 are compared in figure 5.

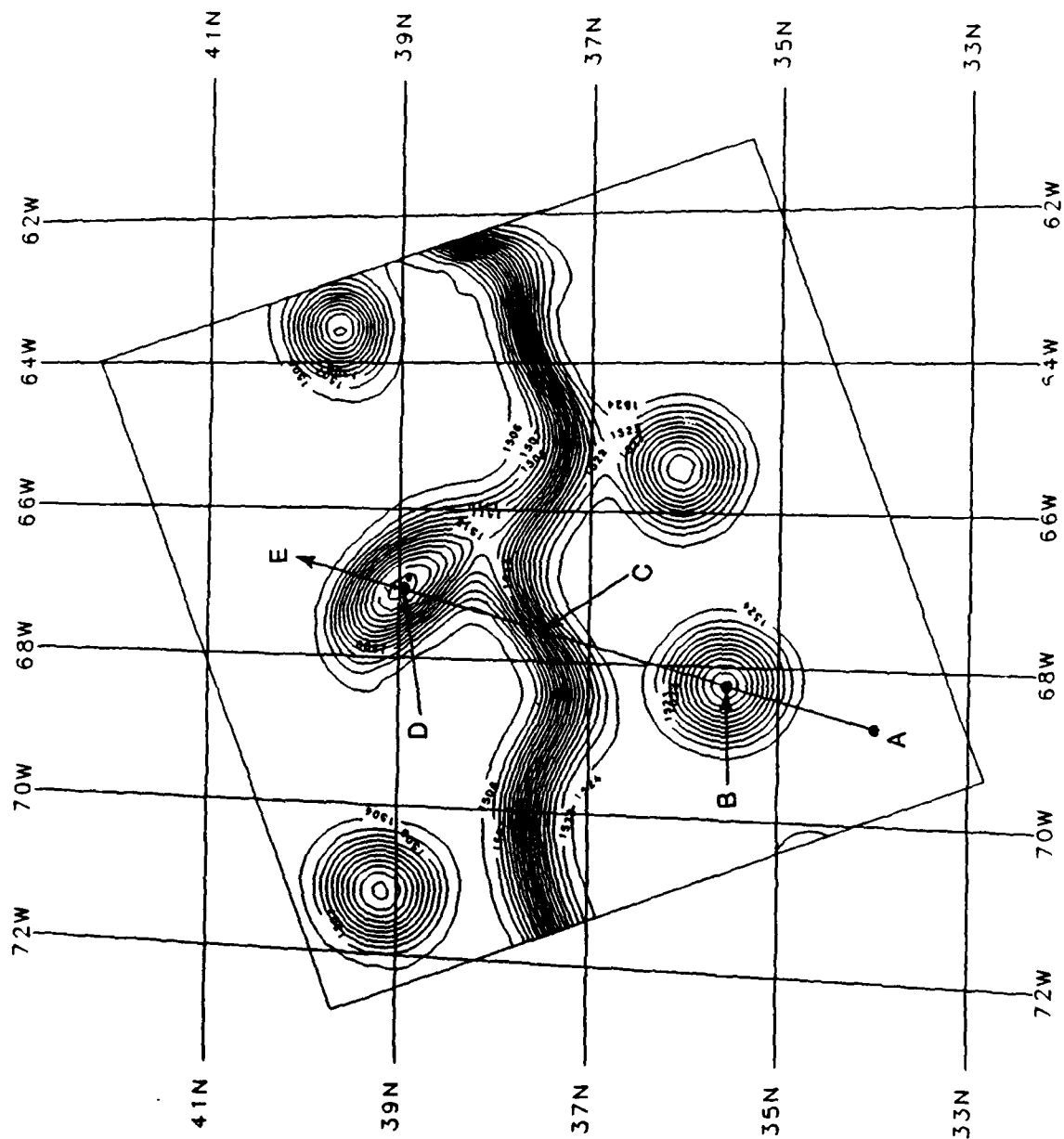


Figure 1. Harvard University Gulfcast, 16 August 1986,
Sound Speed at 100 Meters

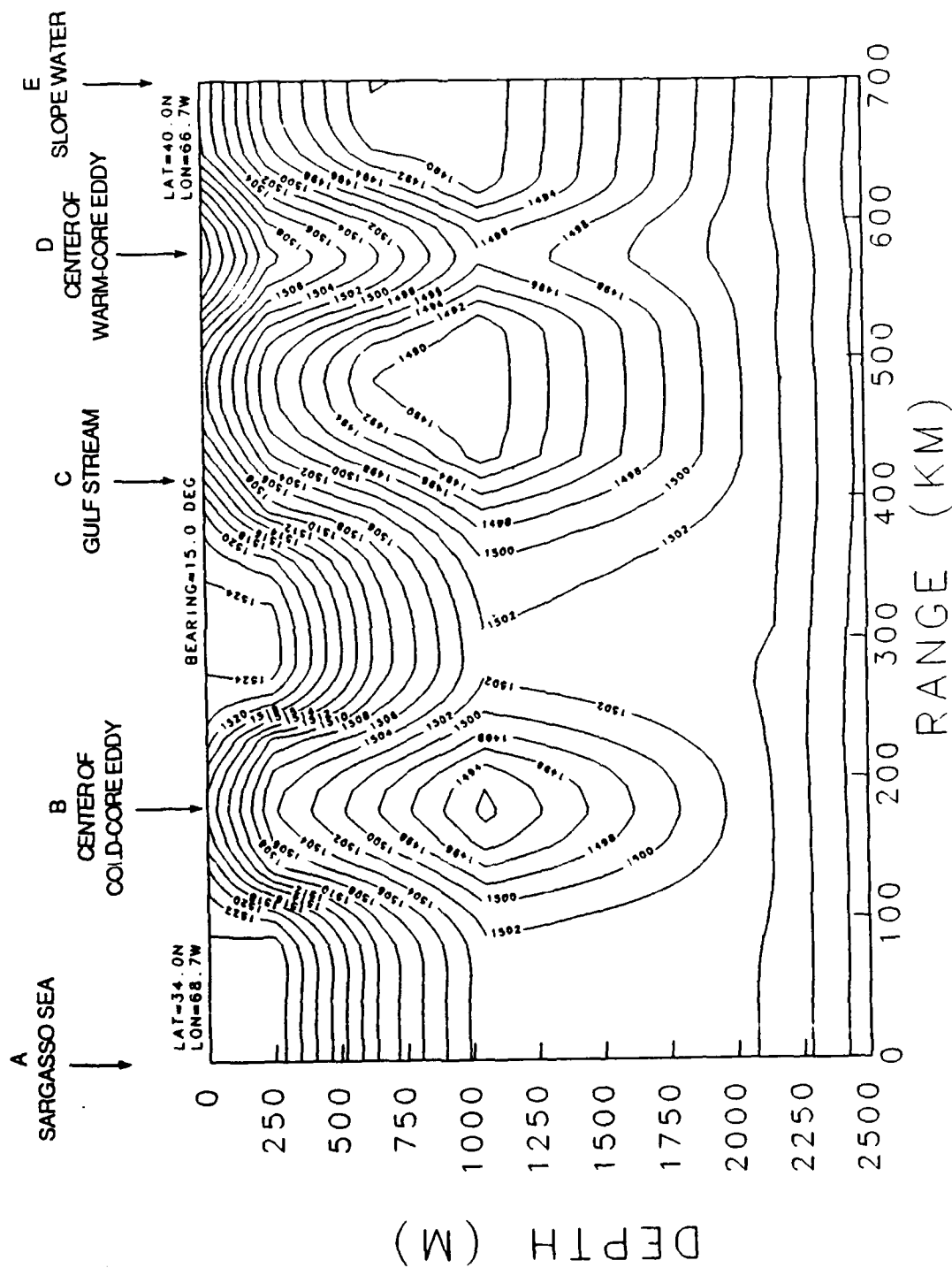


Figure 2. Harvard University Gulfcast, 16 August 1986.
Sound Speed in the Vertical Plane

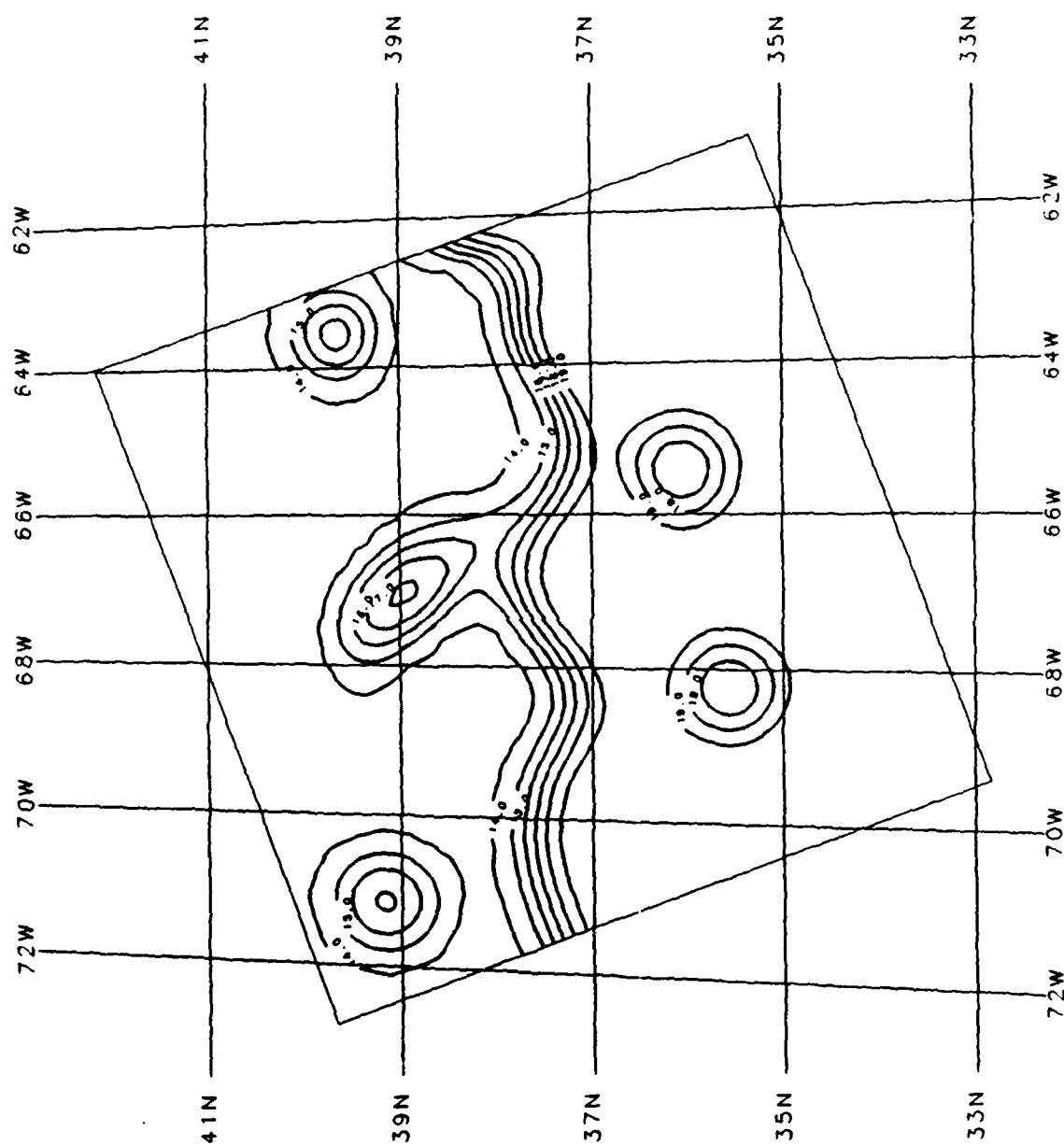


Figure 3. Harvard University Gulfcast, 16 August 1986,
Temperature at 100 Meters

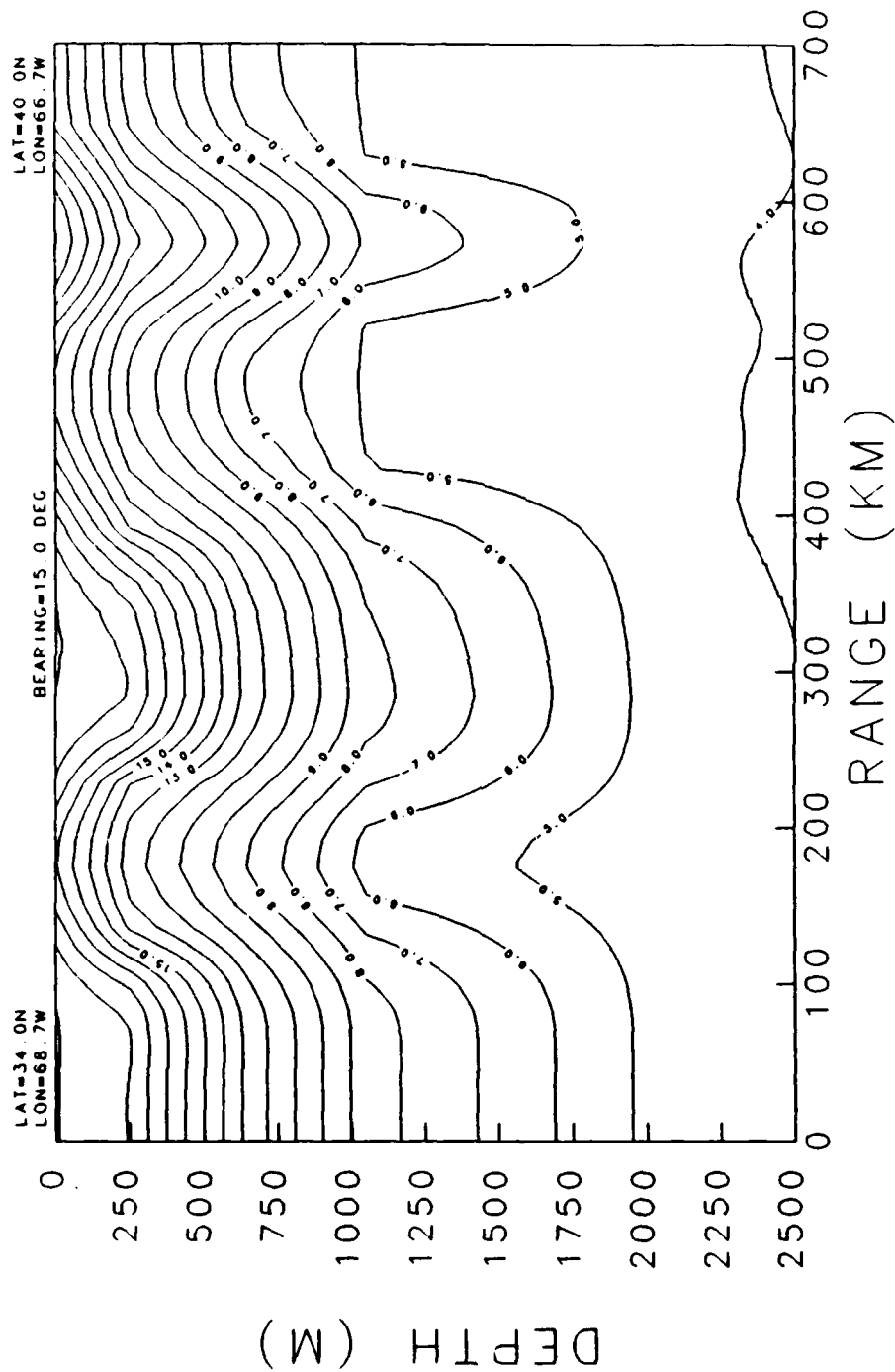


Figure 4. Harvard University Gulfcast, 16 August 1986, Temperature in the Vertical Plane

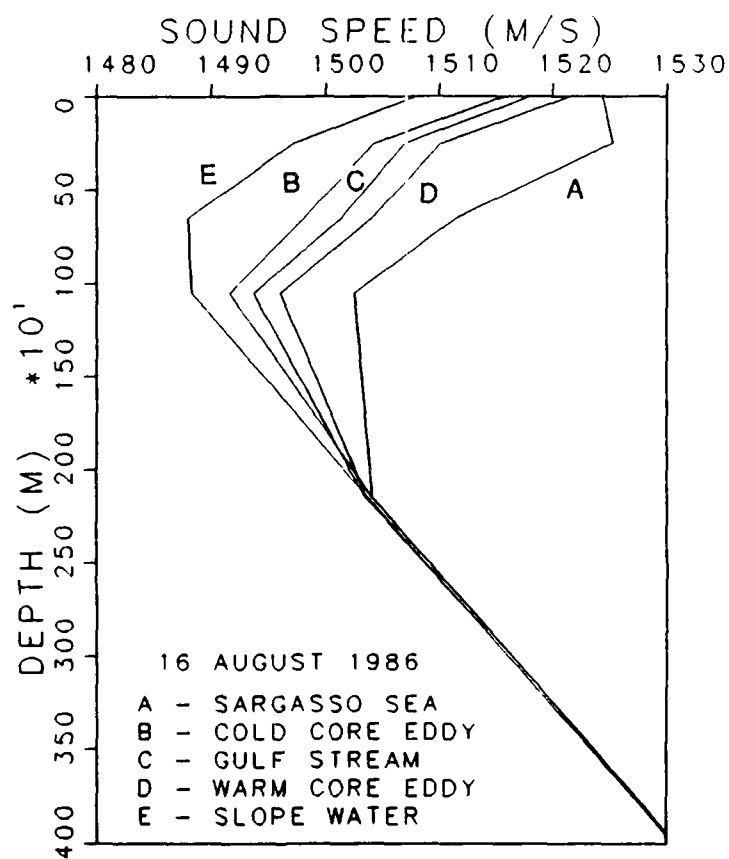


Figure 5. Sound Speed Profiles Along the Transect ABCDE

INTERFACING IFD AND THE HARVARD DATA SET

In order to interface IFD with the Harvard data set without altering the present structure of the input runstream or modifying the IFD model, a data-dependent subroutine, USVP, was written and stored in a file named HVDSVP2D.FOR. A variety of predictions through the Harvard data set may be generated by modifying USVP.

SUBROUTINE USVP

As previously reported,² IFD calls on user-prepared subroutine USVP whenever the input sound speed flag, KSVP, is not set to zero. When called, subroutine USVP locates the position of the next solution to be obtained, enters the Harvard data set, and extracts the sound speed profile at that location. A flow chart of USVP logic appears in figure 6.

Since USVP is data dependent and not general purpose, the user must edit USVP in order to initialize the parameters and variables declared in the flowchart (figure 6). The subroutine is then compiled and linked with the IFD model.

Commands for compiling and linking are as follows:

```
$ FOR IFD,DIAG,CRNK,TRID,HNKL,SVP,SFIELD,HVDSVP2D,UFIELD,BCON,SCON
$ LINK IFD,DIAG,CRNK,TRID,HNKL,SVP,SFIELD,HVDSVP2D,UFIELD,BCON,SCON
```

Note that subroutine USVP is contained in file HVDSVP2D.FOR.

INITIALIZATION FOR 16 AUGUST 1986 FORECAST

Data-Dependent Parameters and Variables

The variables and parameters that must be initialized for the 16 August 1986 data set are as follows:

- Parameter NLEV = 6 - Number of depth levels.
- Data ZLEV/100,300,700,1100,2200,3900/ - Depth levels (meters).
- DLATO = 37°30' - Latitude of domain center.
- DLNGO = 66°48' - Longitude of domain center.
- CCW = 20° - Counterclockwise rotation of domain.
- NX = 55 - Number of data points along "x" axis.

- DX = 1500 - Distance between data points (meters).
- NY = 55 - Number of data points along "y" axis.
- DY = 15000 - Distance between data points (meters).
- AUG16.SPD - File name of data set to be assigned.

Once initialized, these data-dependent parameters and variables remain fixed; whereas, certain user variables must be modified to reflect the geometry of the run.

User-Supplied Variables

User variables that direct the IFD model to propagate along a specific track in the Harvard data domain are as follows:

- SLATO = Latitude of source location.
- SLNGO = Longitude of source location.
- PHI = Direction of propagation.
- XZSVP = Maximum depth to extrapolate (meters).

In the next section, these variables are initialized for a test run through a cold-core eddy.

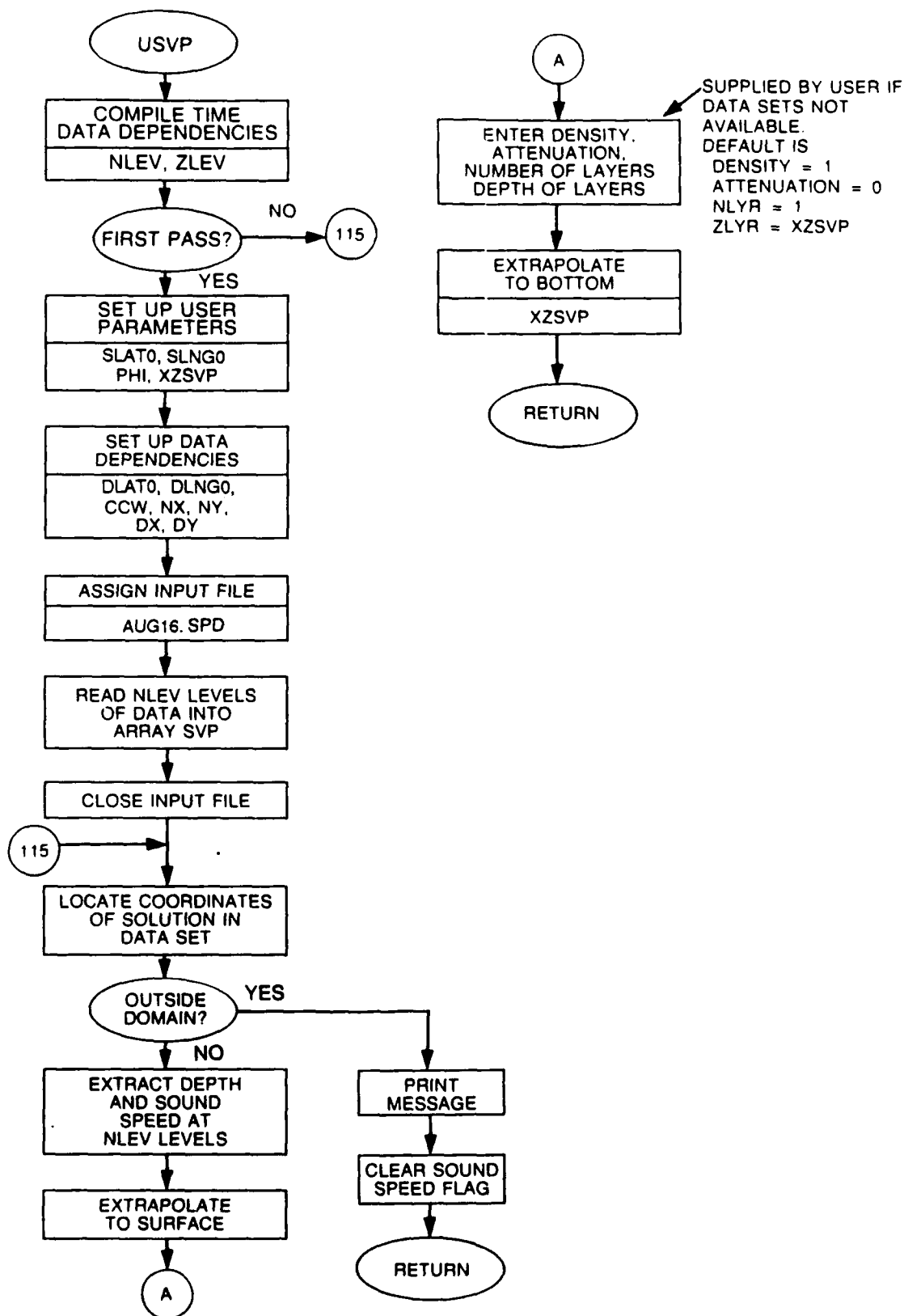


Figure 6. Flowchart of USVP Logic

ACOUSTIC PROPAGATION THROUGH A COLD-CORE EDDY

In this section, the procedure for generating a prediction through a cold-core eddy is included as reference material for IFD users who may have need for generating predictions through Harvard Gulfcasts. Selection of the cold-core eddy was arbitrary.

INITIALIZATION OF USER VARIABLES

In order to propagate through the cold-core eddy located within the first 300 km of the transect ABCDE shown in figure 1, the user must edit USVP in order to assign values to the following variables:

SLATO = 34.0° - Latitude of source location (degrees).

SLNGO = 68.7° - Longitude of source location (degrees).

PHI = 015° - Direction of propagation (degrees).

XZSVP = 5000 - Maximum depth to extrapolate (meters).

Subroutine USVP is then compiled and linked with the IFD model. A listing of subroutine USVP is included in the appendix.

INPUT RUNSTREAM

Once USVP has been linked with IFD, the input runstream (IFD.IN) must be prepared. Explicit instructions for preparing IFD.IN may be found in references 2 and 3 and will not be repeated here.

Parameters for this sample problem are

Frequency = 25 Hz,
 Source depth = 100 m,
 Water depth = 5000 m,
 Sound speed = extracted from Harvard data,
 Density in water = 1.0 g/cubic cm,
 Density in bottom = 1.0 g/cubic cm,
 Attenuation in water = 0,
 Bottom attenuation = 0,
 Artificial absorbing bottom from 5000 - 6000 m,
 Bottom sound speed = sound speed at 5000 m,
 Maximum range = 300 km.

The input runstream located in file IFD.IN is prepared as follows:

```

25 100 0 0 0 6000 600 0 3 0
300000 20 50 50 100000 500 0 0 0
1 .75 1 .25
0 5000
300000 5000
-1,-1
0
1

```

ACOUSTIC PREDICTION

The final step in generating a prediction through the eddy is to run the IFD program. Then output from the model may be plotted with a program such as that listed in reference 2. A plot of propagation loss through the cold-core eddy at 100 meters in depth is shown in figure 7.

In summary, the procedure for generating predictions through the Harvard data set is as follows:

1. Edit USVP to enter data-dependent and user-supplied variables,
2. Compile USVP,
3. Link USVP with the IFD model,
4. Prepare input runstream IFD.IN,
5. RUN IFD, and
6. Plot the contents of IFD.OUT.

IFD SOLUTION
 INITIAL PARAMETERS
 FRQ = 25.0 HZ
 ZS = 100.0 M
 C0 = 1517.8 M/SEC
 R0 = 0.0 M
 Z0 = 6000.0 M
 N = 600
 DR = 20.0 M
 WDR = 50.0 M
 RMAX = 300000.0 M
 DZ = 10.00 M
 WDZ = 50.00 M
 ISF = 0
 IHNK = 0
 ITYPES = 0
 ITYPEB = 3

LYR	DEPTH(M)	RHO	BETA(DB/WL)
1	5000.0	1.00	0.000
2	6000.0	1.00	0.000

 AVG = 50 M
 RECEIVER DEPTH = 100.0 M

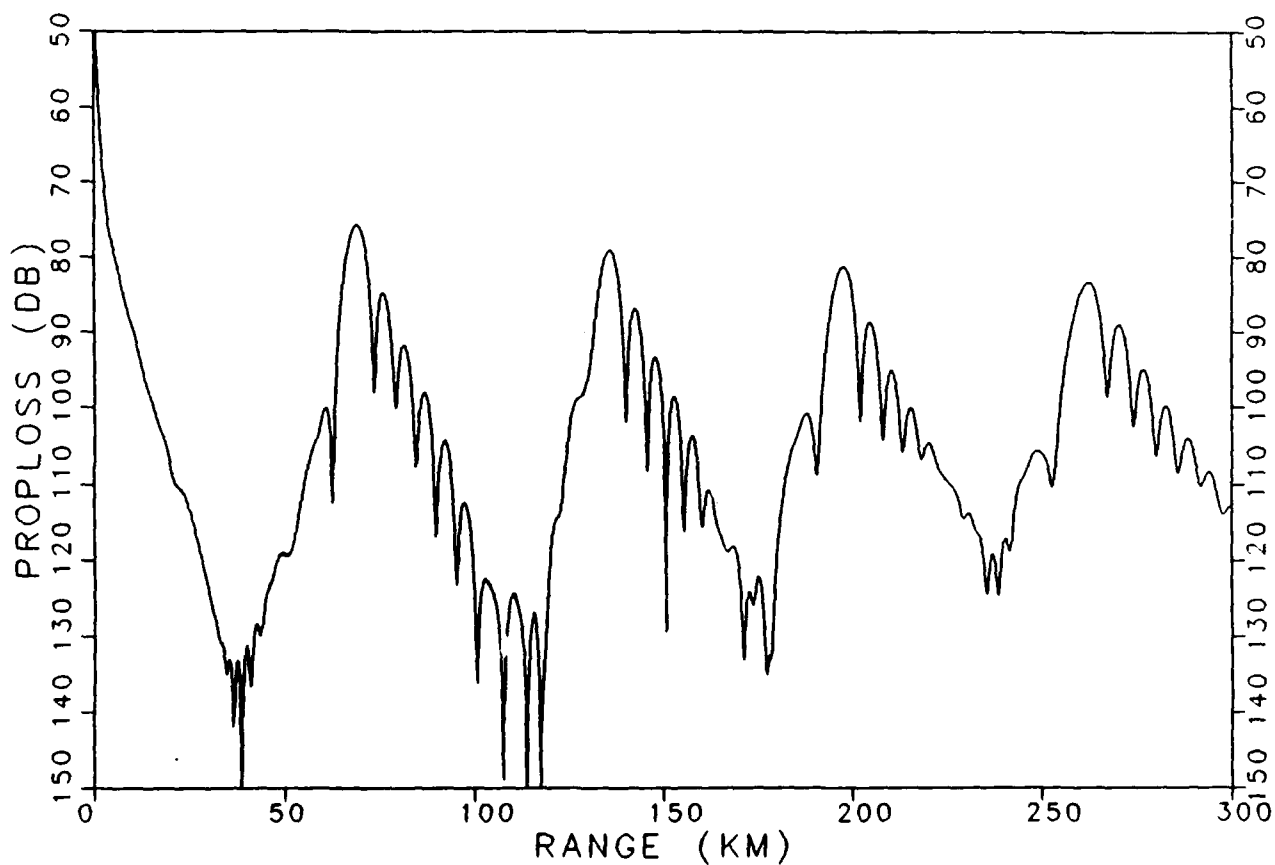


Figure 7. Propagation Loss Through a Cold-Core Eddy

CONCLUSIONS

The IFD computer model has been interfaced with mesoscale sound speed forecasts generated by the Harvard Open Ocean Model. Acoustic propagation predictions through a variety of dynamic undersea environments may now be easily obtained. Sufficient detail has been presented such that the IFD user will be able to modify the interface subroutine, USVP, to accommodate new forecasts. Additional data sets containing density and bottom topography within the domain of interest will be incorporated into USVP in the near future.

Mesoscale forecasts generated by the Harvard Open Ocean Model have also been interfaced with FOR3D,^{11,12} a computer model for solving the LSS three-dimensional, wide angle wave equation. That report will appear at a later date.

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APPENDIX
COMPUTER LISTING OF SUBROUTINE USVP

```

SUBROUTINE USVP
C *****
C * THIS ROUTINE SERVES AS AN INTERFACE BETWEEN THE IFD MODEL AND
C * THE HARVARD OPEN OCEAN MODEL. GIVEN THE LATITUDE AND LONGITUDE
C * OF THE SOURCE AND DIRECTION OF PROPAGATION, THIS ROUTINE EXTRACTS
C * SOUND VELOCITY PROFILES FROM A 3-DIMENSIONAL DATA SET GENERATED
C * BY THE HARVARD MODEL. THIS ROUTINE IS DATA DEPENDENT AND NOT
C * GENERAL PURPOSE. DATA AND RELEVANT PROGRAMS WERE OBTAINED FROM
C * DRS. SCOTT GLENN AND WAYNE LESLIE OF HARVARD UNIVERSITY.
C *****
C *****
PARAMETER HU=3,MXY=10000
PARAMETER MXLYR=101,MXN=10000,MXSVP=101,MXTRK=101,NIU=1,
C      NOU=2,NPU=6
COMPLEX ACOFX,ACOFY,BCOF,BOTX,BOTY,BTA,HNK,HNKL,SURX,SURY,TEMP,
C      U,X,Y
COMMON /IFDCOM/ACOFX,ACOFY,ALPHA,BCOF,BETA(MXLYR),BOTX,BOTY,
C      BTA(MXN),C0,CSVP(MXSVP),DR,DR1,DZ,FRQ,IHNK,ISF,ITYPEB,
C      IYPES,IXSVP(MXLYR),KSVP,N,N1,NLYR,NSVP,NWSVP,R12(MXN),RA,
C      RHO(MXLYR),RSVP,SURX,SURY,THETA,TRACK(MXTRK,2),U(MXN),
C      X(MXN),XK0,Y(MXN),ZA,ZLYR(MXLYR),ZP,ZS,ZSVP(MXSVP)
DATA PI/3.141592654/,DEG/57.29578/
C *** NLEV IS NUMBER OF SOUND SPEED DEPTHS IN HARVARD DATA SET
PARAMETER NLEV=6
DIMENSION SVP(MXY,NLEV),ZLEV(NLEV)
DATA ZLEV/100,300,700,1100,2200,3900/
C *** ZLEV IS DATA DEPENDENT. ZLEV CONTAINS NLEV SOUND SPEED DEPTHS.
DATA IPASS/0/
DATA RAD/6378400/ ! RADIUS OF EARTH IN METERS
GO TO (100,200,300,400),KSVP
NSVP=0
RETURN
100 CONTINUE
IF(IPASS.EQ.1) GO TO 115
C *** INSERT USER PARAMETERS HERE
SLAT0=34.0 ! LATITUDE OF SOURCE
SLNG0=68.7 ! LONGITUDE OF SOURCE
PHI=015.0 ! DIRECTION OF PROPAGATION IN DEGREES
C *** EXTRAPOLATE PROFILE FROM MAX DEPTH GIVEN IN HARVARD DATA SET
C *** TO XZSVP METERS.
XZSVP=5000.0
C *** END OF USER PARAMETERS
SLAT=SLAT0
SLNG=SLNG0
PHI=PHI*PI/180.0
C *** COMPUTE METERS PER DEGREE OF LATITUDE
CONVLAT=2*PI/RAD/360.0
C *** FOLLOWING PARAMETERS ARE FOR HARVARD DATA SET
DLAT0=37.5 ! LATITUDE OF DOMAIN CENTER
DLNG0=66.0+48.0/60.0 ! LONGITUDE OF DOMAIN CENTER
CCW=20.0*PI/180.0 ! COUNTER-CLOCKWISE ROTATION OF DOMAIN IN RADIAN
NX=55 ! NUMBER OF POINTS ALONG X-AXIS
NY=55 ! NUMBER OF POINTS ALONG Y-AXIS
NXY=NX*NY ! TOTAL NUMBER OF DATA POINTS PER DEPTH LEVEL

```

```

DX=15000 ! RESOLUTION IN METERS
DY=15000 ! RESOLUTION IN METERS
CALL ASSIGN(HU,'AUG16.SPD') ! ASSIGN HARVARD DATA FILE
C *** READ HARVARD DATA SET
DO 110 L=1,NLEV
  READ(HU,END=192)NN,T,ITYP,K,TMP1,TMP2
C *** NN = NUMBER OF POINTS IN HORIZONTAL PLANE.
  IF(NN.NE.NXY)GO TO 190
  READ(HU)(SVP(I,L),I=1,NXY)
110 CONTINUE
  CALL CLOSE(HU)
C *** END OF HARVARD INPUTS
  CONVLNG2=RAD*COS(PI*DLAT0/180.)*2*PI/360.0
  XBASIN=(NX-1)*DX
  YBASIN=(NY-1)*DY
  ANGLE=CCW+ATAN2(YBASIN,XBASIN)
  DCENTER=SQRT((XBASIN/2)**2+(YBASIN/2)**2)
  RAOLD=RA
  IPASS=1
115 CONTINUE
  CONVLNG=RAD*COS(PI*SLAT/180.)*2*PI/360.0
C *** LOCATE COORDINATES IN DATA SET
  STHETA=90.0*PI/180.0-PHI
  SLAT=SLAT0+RA*SIN(STHETA)/CONVLAT
  SLNG=SLNG-(RA-RAOLD)*COS(STHETA)/CONVLNG
  RAOLD=RA
C   WRITE(6,*)'LAT = ',SLAT,' LON = ',SLNG
  A1=((DLNG0+DCENTER*COS(ANGLE)/CONVLNG2)-SLNG)*CONVLNG2
  B1=(SLAT-(DLAT0-DCENTER*SIN(ANGLE)/CONVLAT))*CONVLAT
  C1=SQRT(A1**2+B1**2)
  PSI=ATAN2(B1,A1)-CCW
  IS=INT(C1*COS(PSI)/(DX))+1
  IF(IS.GT.NX) THEN
    WRITE(NPU,194)
    KSVP=0
    RETURN
  ELSE
    ENDIF
  JS=INT(C1*SIN(PSI)/(DY))+1
  IF(JS.GE.NY) THEN
    WRITE(NPU,195)
    KSVP=0
    RETURN
  ELSE
    ENDIF
  IF(IS.LT.1) THEN
    WRITE(NPU,194)
    KSVP=0
    RETURN
  ELSE
    ENDIF
  IF(JS.LT.1) THEN
    WRITE(NPU,195)
    KSVP=0

```

```

RETURN
ELSE
ENDIF
XIP=C1*COS(PSI)
YJP=C1*SIN(PSI)
A2=DX*(IS-1)
B2=DX*(JS-1)
C2=SQRT(A2**2+B2**2)
PSI2=ATAN2(B2,A2)
XIS=C2*COS(PSI2)
YJS=C2*SIN(PSI2)
XOFF=(XIP-XIS)/(DX)
YOFF=(YJP-YJS)/(DY)
C *** INTERPOLATE
DO 120 LEV=1,NLEV
I1=(JS-1)*NX+IS
I2=I1+1
I3=I1+NX
I4=I1+NX+1
P1=SVP(I1,LEV)
P2=SVP(I2,LEV)
P3=SVP(I3,LEV)
P4=SVP(I4,LEV)
A=(YOFF*P3+(1.0-YOFF)*P1)
B=(YOFF*P4+(1.0-YOFF)*P2)
CSVP(LEV+1)=(A*(1.0-XOFF)+B*XOFF)
ZSVP(LEV+1)=ZLEV(LEV)
120 CONTINUE
ZSVP(1)=0.0
C *** SPEED AT SURFACE NOT SUPPLIED. USE SPEED AT SHALLOWEST DEPTH OR
C CSVP(1)=CSVP(2)
C *** EXTRAPOLATE TO SURFACE.
CSVP(1)=CSVP(3)-(CSVP(3)-CSVP(2))*(ZSVP(3))/
C(ZSVP(3)-ZSVP(2))
ZLYR(1)=XZSVP
RHO(1)=1.0
BETA(1)=0.0
IXSVP(1)=NLEV+2
NLYR=1
NSVP=NLEV+2
180 CONTINUE
C *** EXTRAPOLATE TO BOTTOM DEPTH XZSVP
ZSVP(NLEV+2)=XZSVP
CSVP(NLEV+2)=CSVP(NLEV)+(CSVP(NLEV+1)-CSVP(NLEV))*(ZSVP(NLEV+2)-
CZSVP(NLEV))/(ZSVP(NLEV+1)-ZSVP(NLEV))
RETURN
190 CONTINUE
WRITE(NPU,191)
191 FORMAT(1X,'DATA MISMATCH. NX*NY DOES NOT EQUAL NN.')
```

NSVP=0

```

RETURN
192 WRITE(NPU,193)
193 FORMAT(1X,'READ ERROR. CHECK INPUT SOUND SPEED FILE.')
```

NSVP=0

```

      RETURN
194  FORMAT(1X,'LONGITUDE OUTSIDE LIMITS OF SOUND SPEED DOMAIN.')
195  FORMAT(1X,'LATITUDE OUTSIDE LIMITS OF SOUND SPEED DOMAIN.')
196  FORMAT(1X,'LAT = ',F6.1,' LON = ',F6.2)
200  CONTINUE
300  CONTINUE
400  CONTINUE
      NSVP=0
      RETURN
      END

```

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